

FORSTERITE-BEARING TYPE B CAI WITH A RELICT ERINGAITE-BEARING ULTRA-REFRACTORY CAI

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Introduction: Forsterite-bearing Type B (FoB) Ca,Al-rich inclusions (CAIs) are a rare type of coarse-grained igneous CAIs found almost exclusively in CV3 chondrites [1–5]. Here we describe the mineralogy, petrography, and oxygen-isotope compositions of a FoB CAI *Al-2* from Allende containing a relict eringaite-bearing ultra-refractory (UR) inclusion. Eringaite is a Sc-rich garnet $[\text{Ca}_3(\text{Sc,Y,Ti})_2\text{Si}_3\text{O}_{12}]$ that has been recently identified in a cluster of UR inclusion fragments within an amoeboid olivine aggregate in Vigarano [6].

Results: The Allende CAI *Al-2* is a coarse-grained igneous inclusion, $\sim 7 \times 8 \text{ mm}^2$ in size, composed mainly of Al,Ti-diopside, melilite, spinel, and forsterite; anorthite is accessory. Forsterite is heterogeneously distributed in the CAI: the forsterite-rich and spinel-rich (forsterite-poor) lithologies can be identified. The CAI mantle, $\sim 0.6 \text{ mm}$ thick, composed of melilite, anorthite, spinel, and minor hibonite, is forsterite-free. Secondary minerals replacing melilite in the CAI core and mantle include grossular, monticellite, Ti-free Al-diopside, wollastonite, and wadalite. In the peripheral portion, melilite and anorthite are replaced by nepheline, sodalite, and ferroan olivine. The CAI also contains several voids filled by hedenbergite and andradite.

The spinel-rich lithology contains a relict UR CAI composed of multiple irregularly-shaped objects made of spinel, Y-bearing perovskite, and eringaite and surrounded by Sc-rich pyroxene (Fig. 1a). Spinel, perovskite, eringaite, and Sc-pyroxene in the relict CAI and Al,Ti-diopside of the host inclusion have ^{16}O -rich compositions: $\Delta^{17}\text{O}$ ranges from -19 to $-25 \pm 1.8\%$ (2σ) (Fig. 1b). This is in contrast to two other UR CAI-bearing inclusions in CVs analyzed – *3N-24* in a FoB CAI from NWA 3118 and *33E-1* in a FTA CAI from Efremovka [4]. In *3N-24*, Zr,Sc,Y-rich oxides and Zr,Sc-rich pyroxene have ^{16}O -poor compositions ($\Delta^{17}\text{O} \sim -2$ to -5%), whereas spinel in *3N-24* as well as spinel and Al-diopside in the host CAI are ^{16}O -rich ($\Delta^{17}\text{O} \sim -23\%$). In *33E-1*, Zr,Sc,Y-rich oxides, Y-rich perovskite, and Zr,Sc,Y-rich pyroxenes are ^{16}O -depleted ($\Delta^{17}\text{O} \sim -2$ to -5%) compared to Al,Ti-diopside of the FTA CAI ($\Delta^{17}\text{O} \sim -23\%$). We infer that (i) UR CAI-bearing compound inclusions recorded variations in O-isotope compositions of nebular gas during the earliest stages of the Solar System evolution, and (ii) FoB CAIs formed by melting and evaporation to different degrees of aggregates of refractory inclusions and forsterite condensates [3].

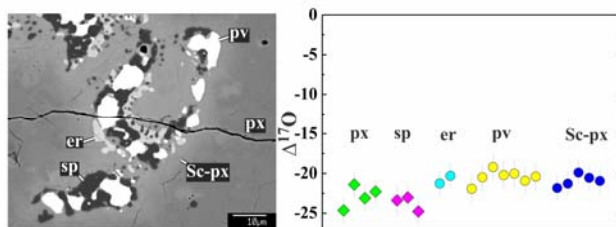


Fig. 1. (a) BSE image and (b) $\Delta^{17}\text{O}$ values of individual minerals in the UR CAI *Al-2*. er = eringaite; pv = perovskite; px = Al,Ti-diopside; Sc-px = Sc-rich Al,Ti-diopside; sp = spinel.

References: [1] Clayton et al. 1984. *GCA* 48:533. [2] Wark et al. 1987. *GCA* 51:607. [3] Bullock et al. 2012. *MAPS* 47:2128. [4] Ivanova et al. 2012. *MAPS* 47:2107. [5] Krot et al. 2014. *GCA* 145:206. [6] Ma. 2012. *MAPS* 47 (Suppl.):#5015.